Honeywell at Bolt Beranek and Newman, Inc.

Produced by Honeywell to be handed out at the ARPANET demo at ICCC '72

Prior to 1968, direct computer-to-computer interaction was a thing of the future. Time-sharing systems permitted a number of different users to take advantage of the resources of a single large computer, but they limited the user to the capabilities of that system. Resource-sharing among computers was then simply the physical transferring, or copying, of data and/or programs from one machine to another, with restrictions of language standards and identical hardware systems hampering users.

An awareness of the need for computer-to-computer dialogue was felt by ARPA (the Advanced Research Projects Agency) in 1968 because a multitude of dissimilar computers at many ARPA-sponsored research centers across the country needed to access programs and data at other ARPA centers. Thus, development of an efficient, error-free, and cost-effective computer-to-computer communications system was finally about to begin. Such a system would give users direct access to computers at other sites, would permit remote access to specialized hardware and software resources, and would allow and encourage joint problem solving and direct retrieval from remote data bases.

Intent on a solution to these digital communications problems, ARPA selected Bolt Beranek and Newman Inc. (BBN) to develop a responsive, reliable, and economic digital communications system.

Bolt Beranek and Newman Inc., a problem-solving company devoted to consulting, research, and development in the areas of science and technology, was formed in 1948. Today, BBN and its subsidiaries employ approximately 650 people and provide professional services from their headquarters in Cambridge, Massachusetts, six regional offices in the United States and an affiliate in Munich, Germany.

The Problem-Solvers

The ARPA Network

The ARPA-specified criteria for the network included the use of a distributed store-and-forward, packet-switching communications system that would respond to the characteristic needs of computer communications.

A packet-switching system was chosen for the ARPANET over a more conventional circuit-switching system for a number of reasons. For one thing, packet switching provides simultaneous sharing of a wire by many users. Also, "connect" time is shorter providing greater responsiveness; conflicts are resolved dynamically within the system by means of variable delays; and a cyclic check sum, by sensing errors and causing retransfer of a packet if errors occur, has made the ARPANET virtually error-free (estimated less than 1 bit in error per 10^{12} bits sent). Also, in the ARPANET, the path a message follows is not determined in advance, as is the case with conventional circuit switching. The system provides selection of the best path dynamically as the message is transmitted.

Bolt Beranek and Newman Inc. (BBN) made real the ARPA-specified concepts of distributed computing and direct computer-to-computer communications with the development of the ARPANET. Now, hardware sharing, software sharing, data base sharing, and an advanced, reliable, and responsive communications system will be available thanks to the team effort of ARPA, Honeywell and BBN scientists. BBN designed the network hardware and software, tested, shipped, and installed the systems, and currently manages the network operations.

At the heart of the network is a subnet of Honeywell mini-computers. The job of these small computers, called Interface Message Processors (IMPs), is twofold. First, they provide the interface(s) into the network for the large research computer(s), hosts, at each node or computer site in the network. And second, they handle all the communications functions of the system—routing, buffering, sequencing, synchronization, error control, acknowledging, congestion prevention, etc.

The initial computer selected to serve as the IMP throughout the ARPANET was the Honeywell 516. BBN chose the Model 516 because of its fast cycle time, powerful instruction set, proven I/O capability, and high performance record. It is housed in a single, ruggedized cabinet which includes the 12K memory, 16 I/O channels, and the BBN-designed modular interfaces for connecting the IMP to telephone line modems and host computers. Maintenance service is provided by Honeywell on all IMP processors installed in the field.

One of the most significant features of the IMPs is that they operate independently of the hosts. This autonomy is extremely important in the ARPANET because an IMP must continue to function in its role in the store-and-forward communications system, even when its host computer is inoperative. Therefore, the system is constructed so that the IMPs do not depend on the hosts for buffer storage, program reloading, or any other logical assistance. Likewise, IMPs operate independently of, although cooperatively with, each other.

A notable example of the cooperation between IMPs occurs when a program reload is required. If an IMP's operating program is found (through a built-in timing device) to be destroyed, the IMP sends a request for a program reload to a neighboring IMP via one of the 50KB lines through which the IMPs communicate. The responding IMP then sends back a copy of its own program.

Standardization of the IMP operating programs is one of the most important features that BBN incorporated into this system. It is this uniformity that permits program reloading from any neighboring IMP, provides for ease in maintenance, and simplifies debugging and program revision.

Program Reliability/ Recovery

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TERMINAL
INTERFACE
MESSAGE PROCESSOR
INTERFACE
MESSAGE
PROCESSOR

Transmissions between host computers generally vary in size, but a single transmission, or message, may not exceed 8095 bits. A host sends a message by passing it to the IMP through a bit-serial interface. The IMP takes the message from its host, segments it (if necessary) into packets of 1008 bits each and forms a header for each packet to identify the source host, destination host, packet number, etc., and adds a 24-bit cyclic error check sum. Then each packet in the message is routed from IMP to IMP along a path based on each IMP's current estimate of local network delay. This procedure is repeated for each packet, until all packets of the message reach the destination IMP. At this point, the message is reassembled by the destination IMP and passed to the destination host. After error-free reception of a packet, each IMP along the way generates an acknowledgment to the preceding IMP, thus allowing the preceding IMP to relinquish responsibility for its copy of the packet and free that buffer space for storage of another packet. If an error is detected, no acknowledgment is sent and after a suitable delay the originating IMP re-transmits the packet.

Message Handling

The ARPANET clearly provides an invaluable resource-sharing service to the user with a large computer and a sophisticated and extensive software capability. But what of the smaller facility with no special processing capabilities of its own to contribute to the network? For this user, BBN developed the Terminal IMP (TIP). The TIP incorporates Honeywell's Model 316 general-purpose computer and a unique multiline terminal controller developed by BBN. The Model 316 was selected because of its program compatibilities with the Model 516 and its improved cost/performance capabilities. In addition, the Model 316 is now being provided as an IMP to network nodes where the higher bandwidth of the Model 516 is not required.

The TIP acts as both an IMP and a simple host, providing interaction (at rates up to 100 kilobits per second) between any combination of hosts on the network and up to 63 local or remote consoles and/or peripheral devices. A TIP may also serve up to three hosts via IMP-host interfaces. Thus, many diverse kinds of terminals and devices at various sites (with or without network hosts) can have access to the nationwide abundance of computer resources provided by the ARPANET.

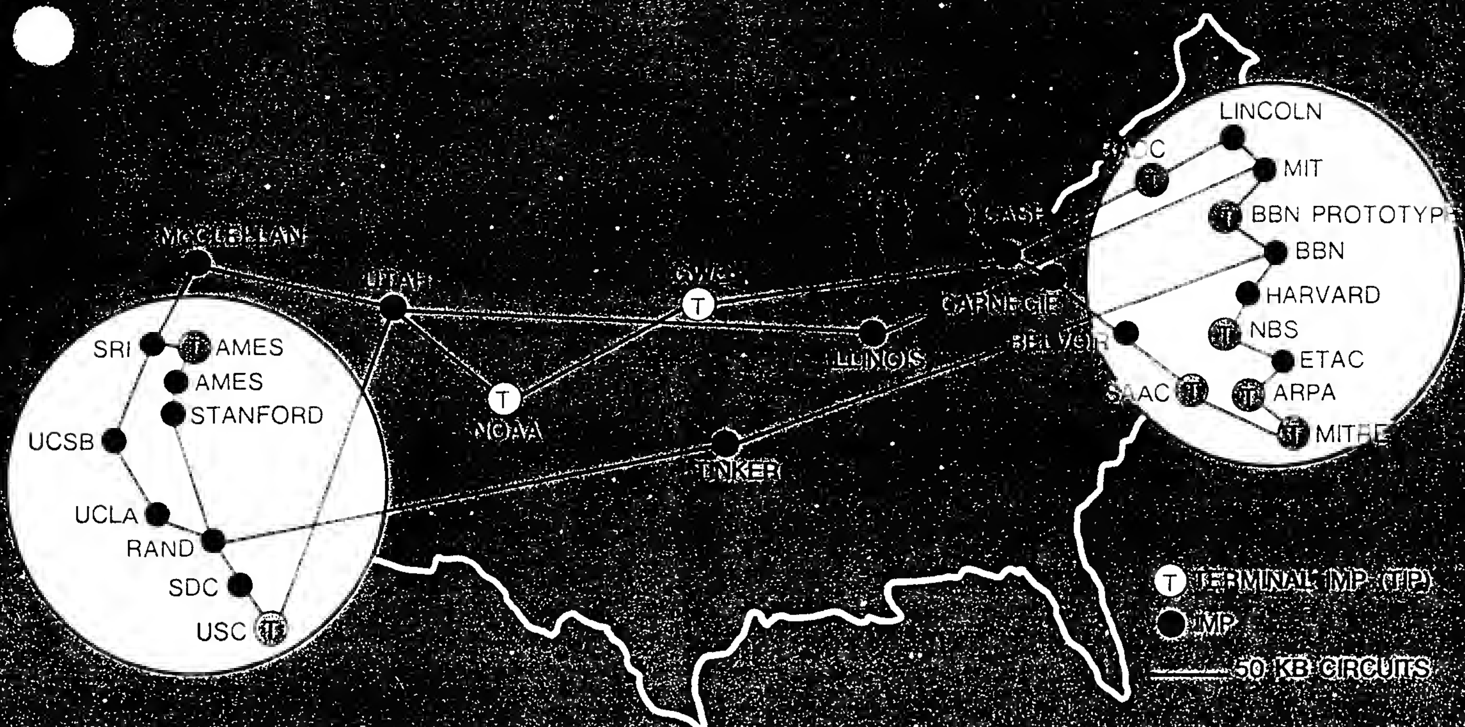
The Terminal IMP (TIP)

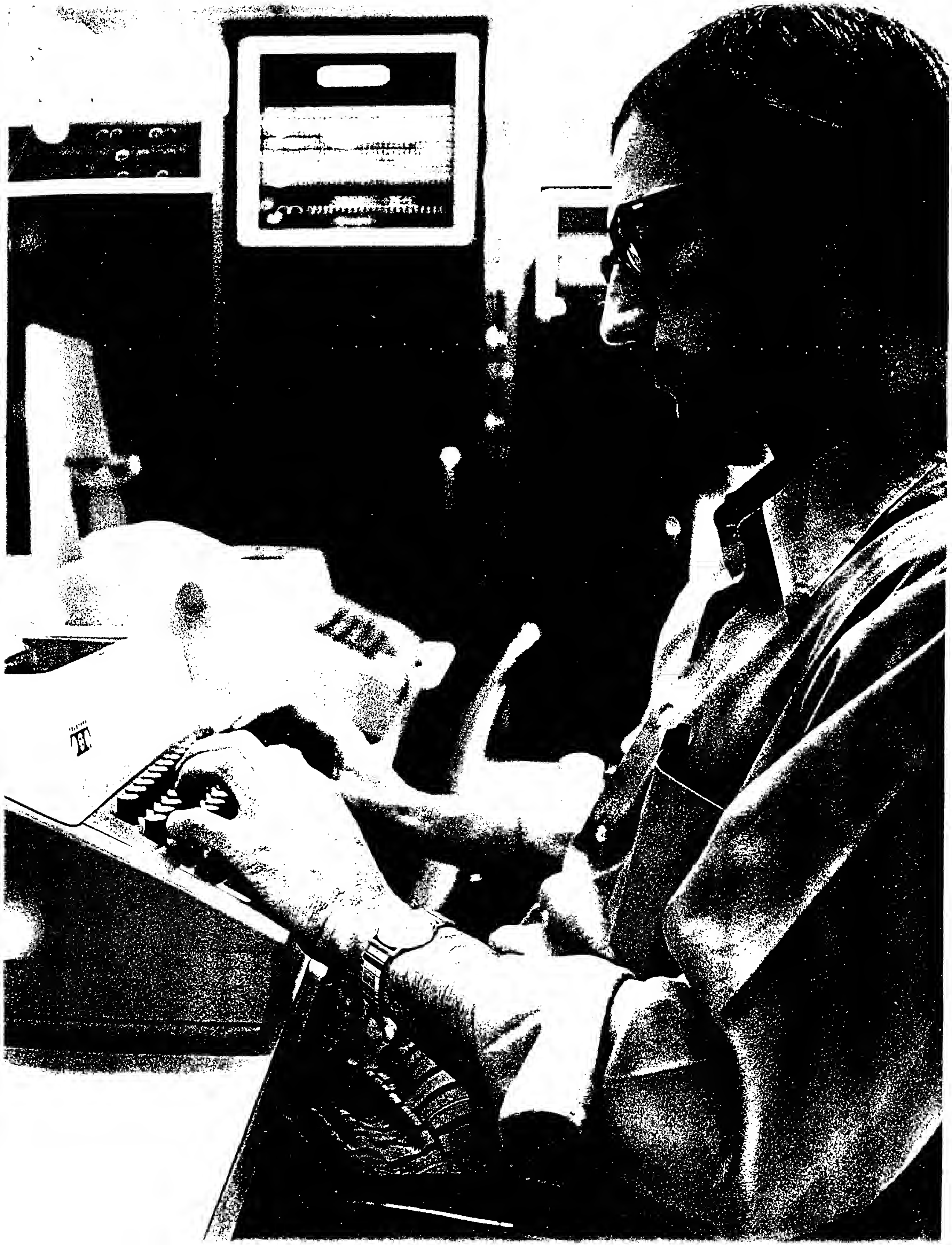
BBN has also developed a Network Control Center (NCC) in Cambridge, Massachusetts. This center performs two significant functions. First, the NCC gathers status reports made by all IMPs concerning the state of the network and of the IMPs themselves. These reports are utilized by NCC personnel to monitor the state of the network; and if failures have occurred, to determine where repair is necessary. The NCC also provides accounting data on network traffic. Again, a Honeywell computer, the same Model 316 that is used for the TIP, serves as the NCC central processor.

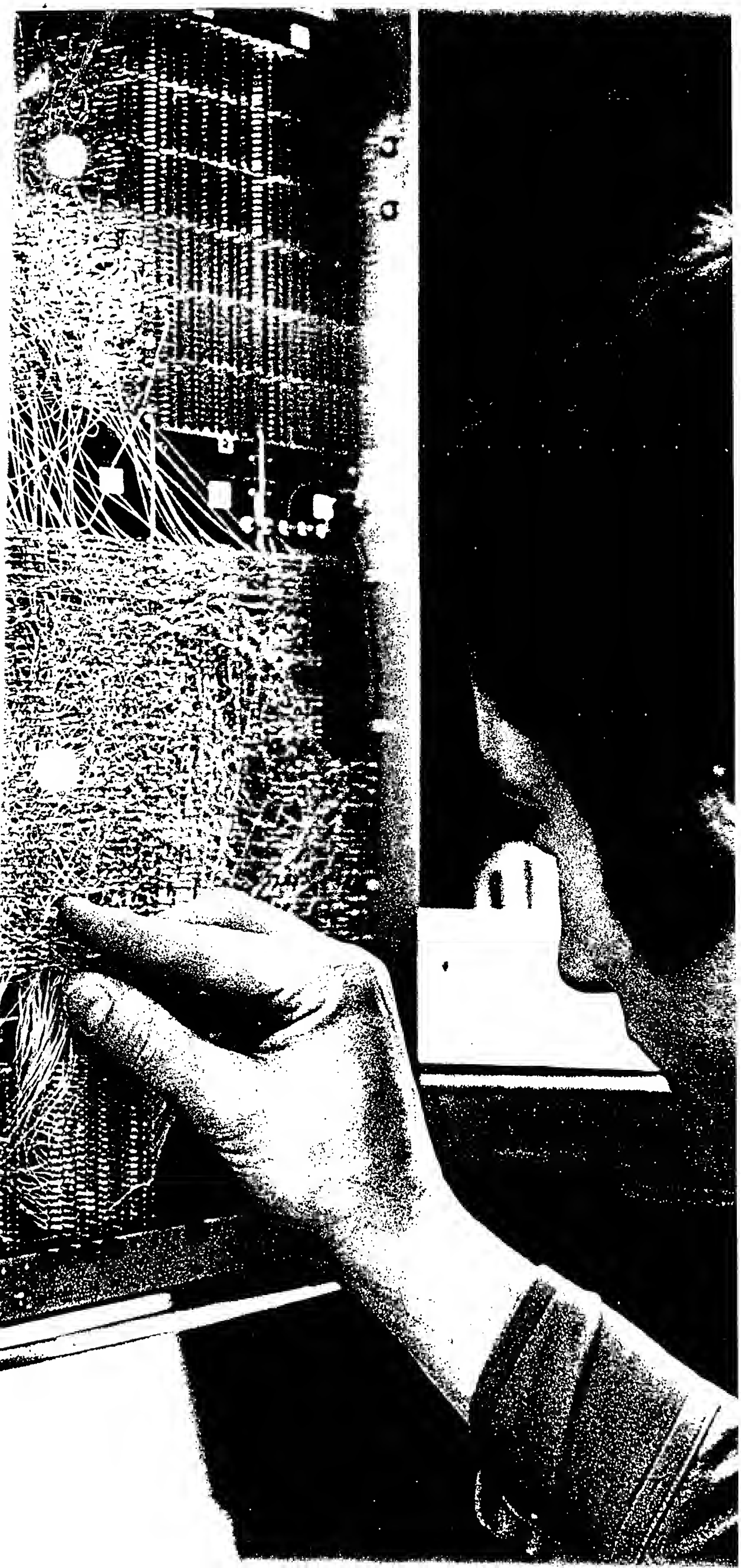
Network Control Center

The map of the ARPANET shown on this page depicts the distribution of users and gives some idea of the network's computer resources. These resources at ARPA-sponsored centers include UCLA's IBM 360/91 and UCSB's IBM 360/75; six TENEX time-sharing systems developed by BBN; MIT's advanced time-sharing system, MULTICS (H-645); and scheduled for operation in March, 1973, the ILLIAC IV computer at the NASA Ames Research Center. Also scheduled for March, 1973 accessibility to users is a trillion bit laser store. Remote job entry terminals will be supported by fourth quarter 1972. Data base sharing and software sharing are two more future capabilities of the ARPANET that will provide users with invaluable operating assets.

Network Resources







BBN began work on the design and development of the ARPANET in January, 1969; the early experimental phase of the system was undertaken in 1970. Now, just three years later, the ARPANET has grown to include over 29 sites across the United States. With a growth rate of about one IMP or TIP per month and constantly increasing use, BBN projects a total of 34 IMPs and TIPs in operation by the end of 1972. In addition, two SIMPs, or satellite IMPs, are scheduled to be installed in Hawaii and in California by December of 1972. Successful operation of the SIMPs using the INTELSATT satellite for communications will open up a new kind of worldwide digital communications. Clearly, the ARPANET represents one of the most significant and valuable advances in computer and communications technology. Virtually unlimited applications are offered by this powerful new communications capability that will certainly provide the computer industry and its users with a strong impetus for new growth.

Today many users of digital communications have installed excess facilities and lines to improve reliability; operated terminal facilities at speeds less than they were capable of; designed and installed costly error detection and correction equipment; and installed costly line equalizers, modems, concentrators, and multiplexers to improve system throughput. In general, industry has "force-fitted" inherently more flexible computer applications to currently available communications.

The packet-switching technology represented by the ARPANET offers a complete digital communication approach which provides more flexible service, lower costs, and increases performance over conventional approaches.

If you operate a data communications system, it could well be a profitable step for you and your company to consider this new technology. The BBN/Honeywell team can help.

The ARPANET Today And Tomorrow